NONINVASIVE CONSTITUTIVE MODEL PARAMETER IDENTIFICATION METHOD FOR ARTERIAL TISSUE

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Introduction

Constitutive models are widely used for the modelling of arterial tissue. The parameters for a model are usually obtained from mechanical experiments which require excision of the arterial sample. However, to use these models in clinical practice, parameter identification needs to be performed based on non-invasive measurements, such as pressure and diameter measurements. This is a challenging task due to the reduced amount of information that can be collected in this way and due to the fact that the pressure range is limited to the physiological range. This abstract presents a non-invasive methodology for parameter identification that copes with this reduced amount of information.

Methods

To have perfectly controlled conditions and exclude the measurements errors, simulated results were used instead of actual measurements. For that purpose a finite element model (FEM) was developed in Abaqus. An artery was modelled as a perfectly circular segment. The constitutive model which has been used was the one proposed in [Gasser, 2006]. The material parameters prescribed in the FEM are shown in Table 1 (Actual) and they correspond to those of a healthy rat abdominal aorta. To include residual stresses which are present in arteries [Cardamone, 2009], different loading steps were applied as shown in Figure 1.

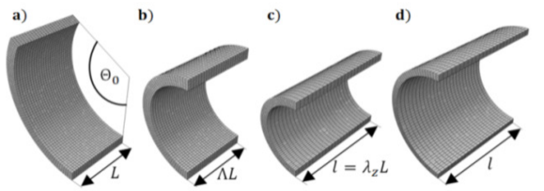

Figure 1: Loading steps: a) stress-free configuration; b) unloaded configuration (closed segment); c) stretched segment; d) loaded configuration.

The applied physiological pressure and outer diameter substitute the experimental measurements needed to perform parameter identification. The non-invasive parameter identification approach consists of a minimization of an objective function expressing the difference between the constitutive model-based internal pressure and the measured pressure, as a function of the arterial diameter. Also included in the objective function is the assumption that the axial force should remain approximately constant in the physiological range. Finally, it was observed that at diastolic pressure the energy should be close to its minimum. This was introduced as an additional constraint regarding the strain energy. The optimization was implemented in MatlabR2010b, using the ‘lsqnonlin’ routine and the ‘trust-region-reflective’ optimization algorithm.

Results

The results obtained from the non-invasive approach were very close to the actual parameters, as can be seen from Table 1. The biggest difference was in the opening angle ($\boldsymbol{\Theta_0}$) and the outer radius for the stress-free configuration ($\boldsymbol{R_o}$).

	$\mu\ [kPa]$	$k_1\ [kPa]$	$k_2\ [-]$	$\alpha\ [°]$
Actual	15	80	5	5
Non-invasive	15.43	77.51	5.00	0.1062
	$\kappa\ [-]$	$\Theta_0\ [°]$	$R_o\ [mm]$	$\lambda_z\ [-]$
Actual	0.2	120	1.14	1.6
Non-invasive	0.2071	75.36	1.74	1.55

Table 1: actual parameters and parameters obtained with the non-invasive approach (the explanation of the parameters can be found in [Gasser, 2006])

Discussion

The results obtained so far, although obtained from a simulated data set, are encouraging. They lead us to believe that obtaining meaningful and trustworthy parameters from non-invasive measurements is possible by introducing additional constraints on the strain energy and assuming that the force remains constant in the physiological pressure range. The next step will be to evaluate this method on experimental measurements performed on mammals. The final goal is to obtain patient-specific material parameters from measurements obtained in a clinical setting.

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References

Cardamone, L et al, Biomech Model Mechanobiol, 8(6): 431–446, 2009.
Gasser, T C et al, J R Soc Interface, 3(6):15–35, 2006.